HEXCEL PRODUCTS INC.
2332 Fourth Street
Berkeley 10, California

COPY NO. 14

# DEVELOPMENT AND EVALUATION

# OF A

# LIGHTWEIGHT ALUMINUM HONEYCOMB CASE

Prepared Under
PICATINNY ARSENAL
CONTRACT NO. DA-04-200-AMC-477(A)
AMCMS CODE NO. 5530.12.50908

PROGRESS REPORT #4
R&D 6065
HEXCEL RESEARCH
ADVANCED STRUCTURES GROUP

SUBMITTED: M. N. Bandak

M. N. Bandak, Head, Advanced Structures Group (Acting)

REVIEWED: M. I. Kazimi

M. I. Kazimi, Senior Scientist

APPROVED:

E. C. Vicars, Research Director

May 13, 1964

# TABLE OF CONTENTS

## FOREWORD

This report has been prepared by the Research Division, Advanced Structures Group, Hexcel Products, Inc., Berkeley 10, California, under Picatinny Arsenal Contract No. DA-04-200-AMC-477(A), Hexcel Project No. 6065 - "Development and Evaluation of a Lightweight Aluminum Honeycomb Case". The report covers work accomplished during the month of April 1964.

## 1. TEST PLAN

The test plan has been revised to delete the temperature-shock, temperature and humidity, and altitude tests from the Phase I testing. An edge drop test has been added for Case HXL-3-477. The revised test plan is shown in Table 2.

## 2. SUPPLEMENTARY TESTING ON CASE HXL-1-477

After drop testing was completed, the end caps were removed and the potting in the ends of the energy absorption cylinder was cut out. Two additional flat drop tests from 36 inches were then performed, the first at a position of 90° from the positions originally tested and the second at 180° from the first. For the second test, the outer skin was removed.

The first test resulted in a peak deceleration of 61.5 g's and an average deceleration of 45 g's. The second test, with both potting and skin removed, resulted in a peak deceleration of 41 g's.

## 3. DESIGN OF CASE HXL-2-477

### 3.1 Evaluation of Tests on Case HXL-1-477

The test evaluation was reported in Progress Report #3. A summary of the results is given below.

a. The potting used to fill in the exposed core around the edges of the end caps and in the ends of the energy absorption cylinder was too stiff. Thus, the potting contributed to the strength of the case in both the flat and end drop conditions, resulting in high peak g values.

b. The .012" outer skin was too rigid, thus preventing the core from being fully utilized as an energy absorber.

c. The contact area of the energy absorption cylinder and the end caps was too large, again resulting in higher peak g values.

d. The potting used in the case was not water tight. Thus, water leaked into the energy absorption core through the potting in the end cap edges, the ends of the energy absorption cylinder core, and the slits in the outer skin of the energy absorption cylinder.

e. The inner skin of the end caps was not sufficiently rigid. Thus, the load was carried only by the ring-shaped area around the cap which was supported by the cylinder, resulting in a non-uniform deformation of the caps. See page 24 of Progress Report #3.

f. The manufacturing tolerance on the installation of the support ring with the hydrostatic cylinder was too large, permitting water leakage into the interior of the hydrostatic cylinder.

3.2 Design Modifications for Case HXL-2-477

The design of the case was modified using the results of the evaluation of the testing on Case HXL-1-477. The design changes are summarized below.

a. The potting was removed (see 3.1.a).

b. The outer skin of the energy absorption cylinder was changed to .006 annealed aluminum alloy sheet (see 3.1.b).

c. Slits in the outer skin of the energy absorption cylinder skin were omitted to prevent water leakage (see 3.1.d).

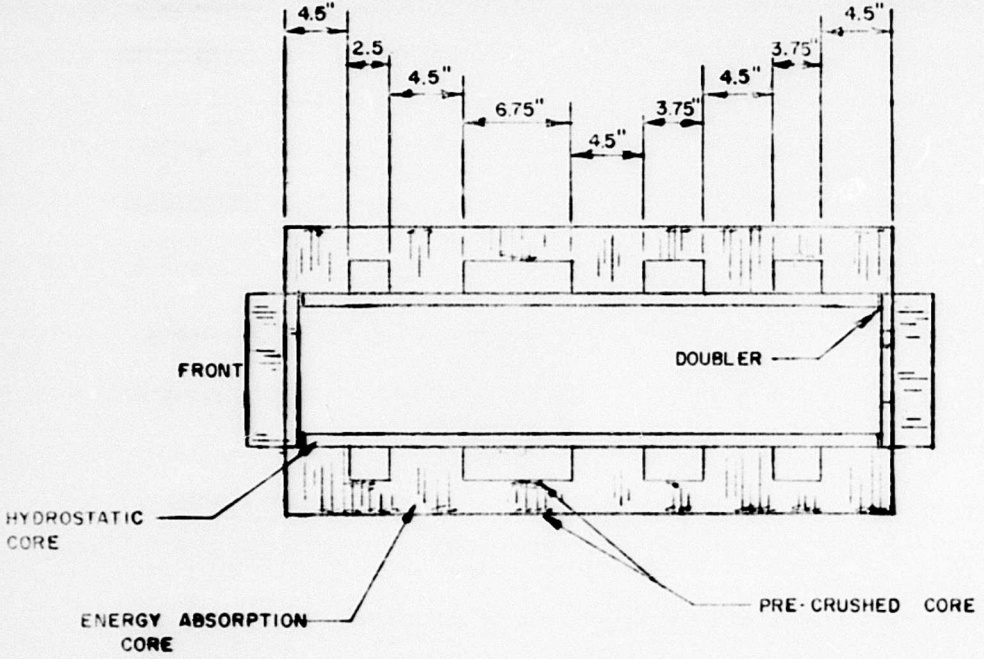
d. All of the exposed core was covered with .000" skin to prevent water leakage (see 3.1.d).

e. The effective contact area of the energy absorption core was reduced. For the cylinder, this was accomplished by cutting circumferential strips out of the core (these strips extended only 2/3 of the circumference; the remainder of the core was solid); for the end caps, by making the outside diameter of the caps smaller (see 3.1.c). This method is illustrated in Figure 1. Reducing the diameter of the end caps reduces the area for the end drops and also for the flat drops because the end caps no longer can carry any load during the flat drops.

f. A reinforcing ring-shaped doubler of .012" thickness was put inside the inner skins of the end caps to increase the stiffness of the end caps for the end drop (see 3.1.e). See Figure 1.

g. A closer tolerance was specified for the installation of the support ring with the hydrostatic cylinder (see 3.1.f).

BLANK PAGE




SECTION

CASE HXL-2-477 ENERGY ABSORPTION CORE FIGURE 1

NOT TO SCALE 5/1/64 F.P.

HEXCEL RESEARCH

BERKELEY, CALIFORNIA

## 4. TESTING OF CASE HXL-2-477

### 4.1 Drop Testing

A summary of the drop testing is given in Table.1. The drops are listed in the sequence in which they were performed. Photographs of the deceleration - time plots for each drop are given in Appendix B.

### 4.2 Hydrostatic Pressure Testing

A 12 p s.i. hydrostatic pressure test was not performed on the case because of the probability that the hydrostatic pressure would collapse the skin in the areas in which circumferential strips of core had been removed. A 22 p.s.i. test following the drop testing was planned. The case was submerged in water, after comp'etion of the drop tests, to check for leaks. Severe leakage into the hydrostatic cylinder was noted all around the rear end cap of the hydrostatic cylinder.

This leakage was caused by damage to the end cap seal due to bottoming out of the energy absorption core during the edge drop. Therefore, the 22 p.s.i. test was not performed.

BLANK PAGE

TABLE 1 - SUMMARY OF DROP TESTS ON CASE HXL - 2 - 477

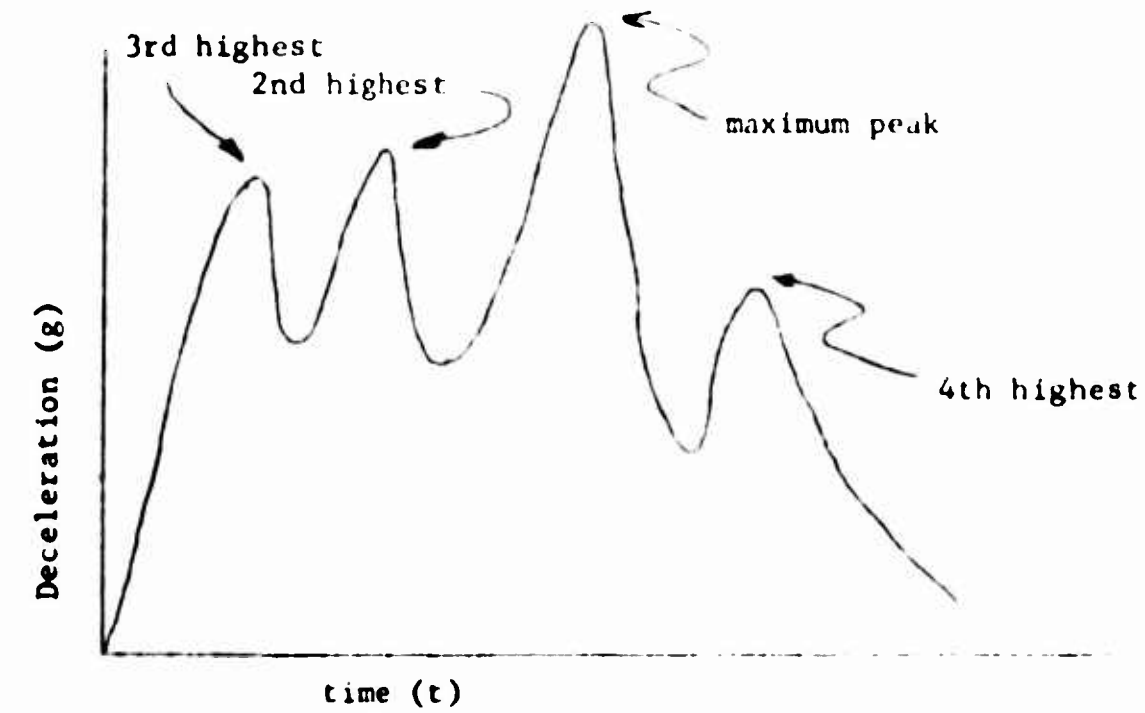
Drop weight: 204.5 lbs.

Drop height: 30 inches. See Figure 2 for explanation of Peak Deceleration and Duration.

| DROP | LOCATION OF DROP | PEAK DECELERATION(g) & DURATION(t=milliseconds) MAXIMUM g | MAXIMUM t | 2ND HIGHEST g | 2ND HIGHEST t | 3RD HIGHEST g | 3RD HIGHEST t | 4TH HIGHEST g | 4TH HIGHEST t | DEFORMATION (inches) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| End | Rear End Cap | 41.7 | 4 | 30.7 | 6 | 32.5 | 5 | | | Bottomed out non-uniformly | |
| Flat | Position#1 (solid core) | - | - | - | - | - | - | | | - | No record of decelerations because of mislocation of microswitch. |
| Flat | Position#1 (solid core) | 27.8 | 7 | | | | | | | 1.3" with width of 10" at front end; 1.35" with width of 10.5" at rear end. | Drop height = 12" |
| Flat | Position#2 (90° from Pos. #1) | 37 | 5 | 31.5 | 3 | 30 | 5 | | | 2" with width of 10.5" at front end; 1.7" with width of 10" at rear end. | 31.5 g peak occurred first. |
| Flat | Position#3 (180° from Pos. #1) | 43.4 | 4 | 40 | 3 | 39.4 | 5 | 34.4 | 3 | | 34.4 g peak occurred first. |
| End | Front end | 32.8 | 4 | | | | | | | Bottomed out non-uniformly | |
| Edge | Rear end | 65.6 | 3 | 37.3 | 3 | 34 | 2 | 20.4 | 2 | Bottomed out at both ends of cylinder with width of 11"; 0.3" on cylinder with width of 3" at 3.5" from rear end. | (a) g values shown are perpendicular to longitudinal axis of case. (b) Edge drop performed after case had been dropped on both ends, destroying most of energy absorption capacity. (c) Drop angle = 24.4° to horizontal. (d) Hydrostatic cylinder was damaged. |

FIGURE 2

TYPICAL DECELERATION - TIME CURVE FOR DROP TESTING




**Note:** Peaks do not necessarily occur in the order shown.

## 4.3 Evaluation of Test Results

### 4.3.1 End Drop Tests

The decelerations during the end drops were within or close to the required 40 g's. However, the reinforcing doublers inside the inner skins of the end caps were still not stiff enough. This can be seen from the non-uniform deformation of the end caps after the end drops.

### 4.3.2 Flat Drop Tests

When the case was dropped during the flat drop test, the initial impact was absorbed by the reduced core contact area (Positions 2 and 3). This resulted in a peak g (31.5 for Position 2 and 34.4 for Position 3). In both cases, the decelerations were higher than the required maximum of 27 g's because the reduction in the core contact area was not great enough. As the core continued to crush, the core over the cut-out areas was pushed inward to fill the gaps. At this point, a full contact area was again available causing one or more peak decelerations higher than the first peak.

4.3.3 Edge Drop Test

When the case was dropped during the edge drop test, it hit on the edge at the rear end giving a maximum peak of 65.0 g's (perpendicular to longitudinal axis). It then bounced and hit on the edge at the front end, resulting in a much lower g value. The high maximum peak was caused partly by the fact that the drop occurred after the end drops which destroyed most of the energy absorbing capacity of the edges. It was also caused partly by the lack of sufficient core to absorb the energy of impact. This resulted in damage to the hydrostatic cylinder with subsequent leakage.

BLANK PAGE

TABLE 2 REVISED TEST PLAN
(Revision No. 3)

| | CASE NO. | HYDROSTATIC PRESSURE 12psi | HYDROSTATIC PRESSURE 22psi | FLAT DROP | END DROP | EDGE DROP | #1 TEMP. SHOCK | #1 TEMP. & HUMIDITY | VIBRATION | #1 ALTITUDE | HOIST STACK | FRAGMENTATION | SALT SPRAY | SAND DUST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PHASE I | HXL-1-477 | 1 | | 2 | 3 | 4 | | | | | | | | |
| | HXL-2-477 | 1 | 5 | 4 | 2 | 3 | | | | | | | | |
| | HXL-3-477 | 1 | 6 | 3 | 4 | 5 | | | 2 | | | 7* | | |
| | HXL-4-477 | 1 | | 2# | | 3# | | | 4# | | | | | |
| | HXL-5-477 | 1 | 5* | 4*2# | | | | | 3# | | | 6* | | |
| PHASE II | HXL-6-477 | 1 | 8 | 7+ | 6 | | | | 4 | 3 | 2# | | | |
| | HXL-7-477 | 1 | | 3# | | 2# | | | | | | | | |
| | HXL-8-477 | 1 | 5** | 2,3+ | 4 | | | | | | | | | |
| | HXL-9-477 | 1 | | | 2 | | 3 | | 4 | | | | | |
| | HXL-10-477 | 1 | | 5# | | 6# | | 3 | 4# | 2 | | | | |
| | HXL-11-477 | 1 | 7* ** | 6* | | | 4* | 3* | 2* | | 5#* | 8* | | |
| | HXL-12-477 | 1 | | 2 | 3 | 4 | | | | | | | | |
| | Specimen 1 Will consist of a case section & samples of hardware (handles, hasps, latches, etc. | | | | | | | | | | | | 1 | |
| | Specimen 2 Will consist of a case section fully representative of complete assembly. | | | | | | | | | | | | | 1 |

* to be conducted at Picatinny Arsenal
\# with saddles on
** tests conducted to destruction
\+ cross drop

NOTES: 1. This is a revised test plan. Additional changes will be made to emphasize a particular phase of test in which the previous units did not give a satisfactory result.
2. For some units, the hydrostatic test is conducted twice. The objective is to see if the drop test, temperature shock, etc. have any effect on the water tightness of the case.
3. Ozone test will be performed on samples of O-rings, gaskets, electrical connectors, and any exposed rubber or plastic parts.
#1 Deleted for Phase I testing.

## APPENDIX A

### STATEMENT OF MAN HOURS EXPENDED - APRIL 1964

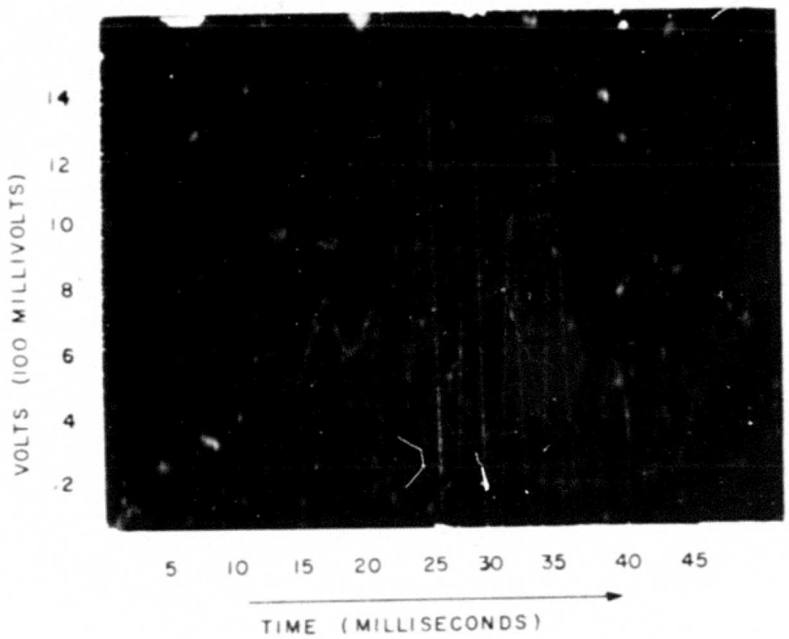
| | MAN HOURS |
|---|---|
| Engineering: | |
| Sr. Professional | 20 |
| Professional | 332 |
| Drafting: | |
| Technician | 143.5 |
| Fabrication: | |
| Technician (Production Specimen) | |
| Other: | |
| Clerical | 26 |
| TOTAL HOURS EXPENDED: | 521.5 |

## APPENDIX B

DECELERATION - TIME PLOTS FOR DROP TESTING

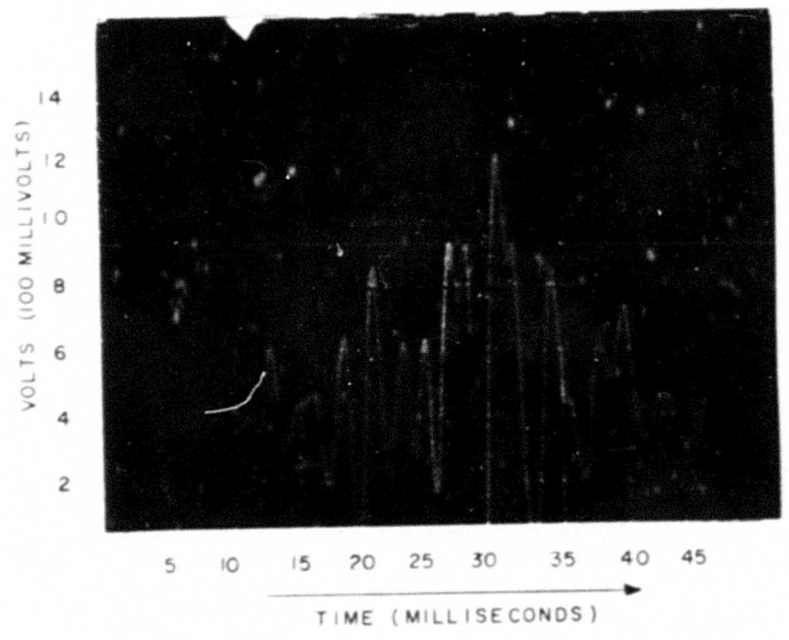
ON CASE HXL-2-477

FRONT END DROP



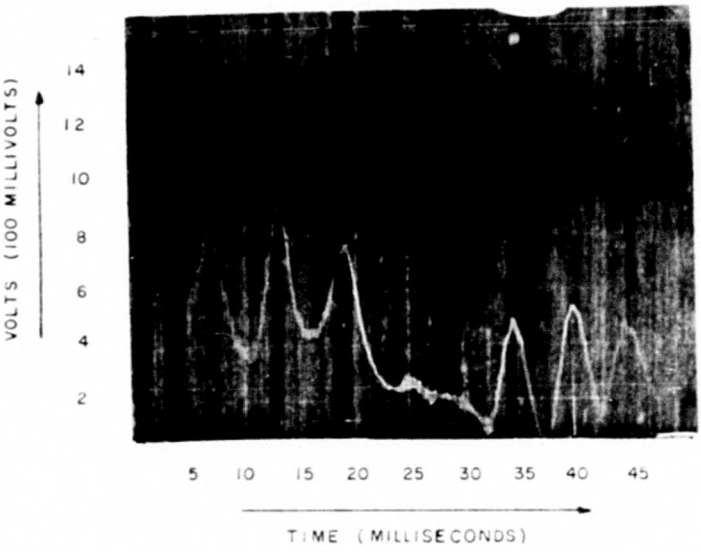

1 G = 12.2 MILLIVOLTS

EDGE DROP



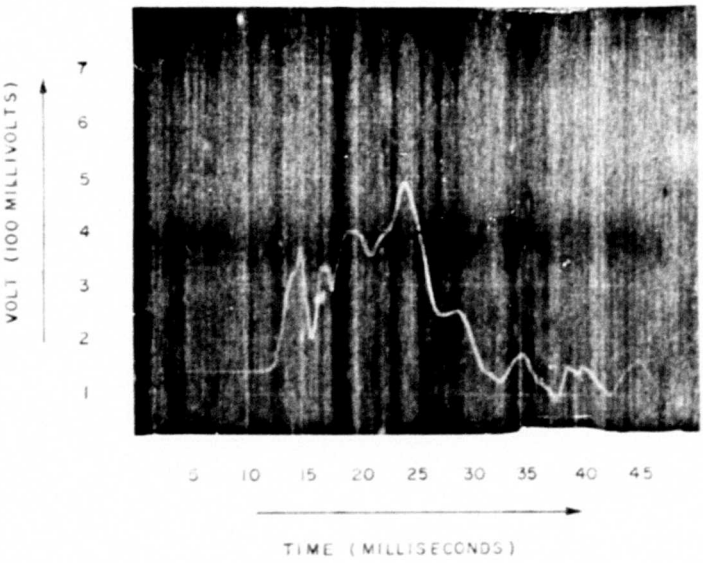

1 G = 12.2 MILLIVOLTS

REAR END DROP



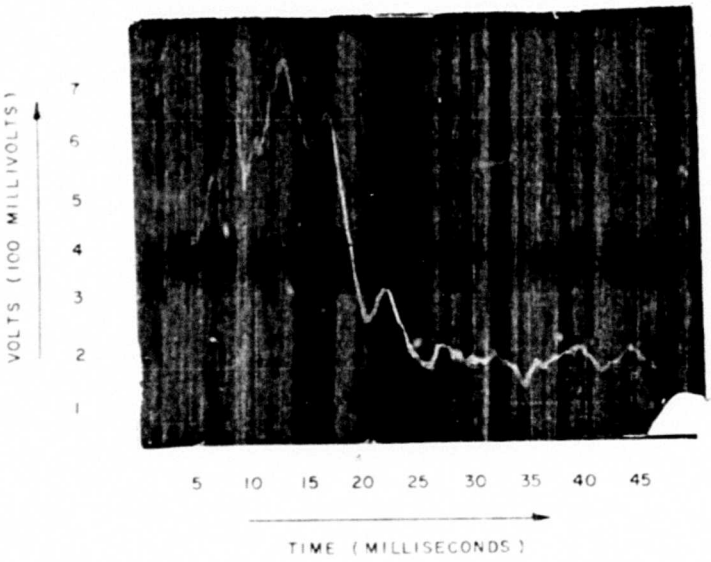

1 G = 12.0 MILLIVOLTS

FLAT DROP
POSITION 1



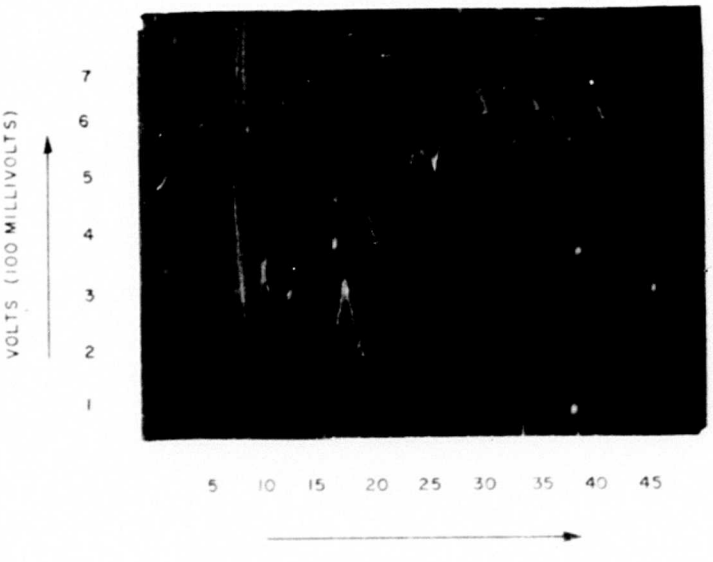

1 G = 12.2 MILLIVOLTS

FLAT DROP
POSITION 2




1 G = 14.6 MILLIVOLTS

FLAT DROP
POSITION 3



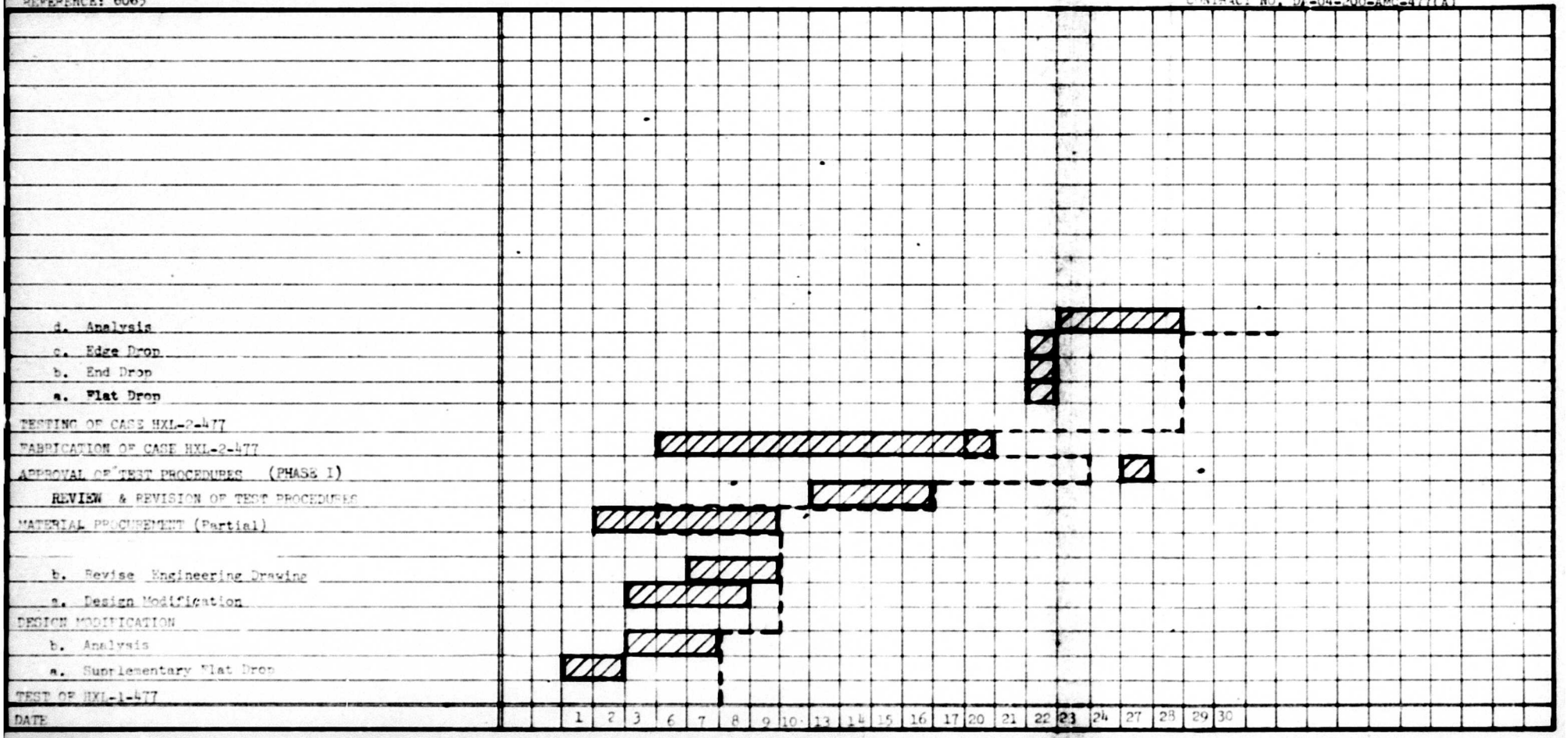

1 G = 12.2 MILLIVOLTS

BLANK PAGE

HEXCEL RESEARCH
REFERENCE: 6065

CHART IV-1
CURRENT PROGRESS
APRIL 1964

CONTRACT NO. DA-04-200-AMC-477(A)



A

HEXCEL RESEARCH
REFERENCE: 6065

CHART 7-2
PROGRAM OF ENSUING ACTIVITIES
MAY AND JUNE 1964

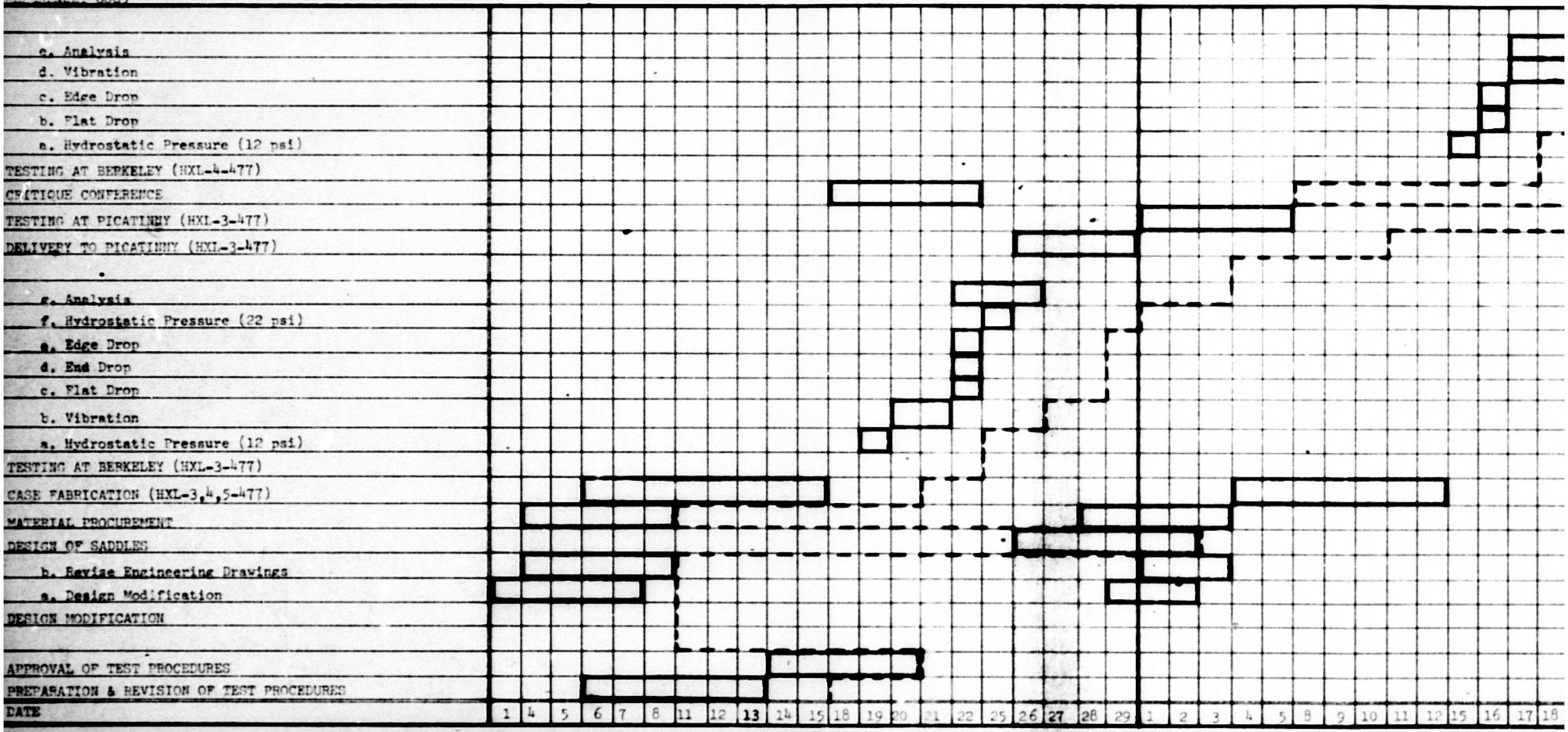


CHART IV-2
PROGRAM OF ENSUING ACTIVITIES
MAY AND JUNE 1964

B